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ABSTRACT

The role of verbalization in children's mental operations was studied by comparing the mental operations children used in spatial perspective tasks (indicating another's view) and rotation tasks (imagining an object's rotation and one's own subsequent view). Each of 96 children (equal numbers of boys and girls, kindergarten and second grade students) was given one of the tasks and asked to respond either verbally or by picture selection. The results indicated that verbalizations led to substantially more correct responses on the perspective task, but not on the rotation task. Errors on the perspective task appeared primarily due to a failure to use the rule that a person in a different vantage point sees a different view, whereas errors on the rotation task appeared primarily due to failures in the computation process of determining exactly the nature of the new view. It was proposed that children manipulate descriptions of object features in perspective taking, while they manipulate more holistic images in rotation tasks. (Author/RL)

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HARVARD PROJECT ZERO

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Technical Report #17

CHILDREN'S ABILITY TO SOLVE SPATIAL PERSPECTIVE AND ROTATION PROBLEMS THROUGH LANGUAGE AND PICTURES

by

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Abstract

To compare the mental operations used by children in spatial perspective tasks (indicating another's view) and rotation tasks (imagining an object's rotation and one's own subsequent view), 96 children (equal numbers of boys and girls, kindergarteners and second graders) were given either task and asked to respond either verbally or by picture selection. The results indicate that verbalizations lead to substantially more correct responses on the perspective task, but not on the rotation task. In addition, errors on the perspective task appear primarily due to a failure to use the rule that a person in a different vantage point sees a different view, whereas errors on the rotation task appear primarily due to failures in the computation process of determining exactly the nature of the new view. These and other results imply that in perspective taking children manipulate descriptions of object features, and in rotation tasks they manipulate more holistic images.

Children's Ability to Solve Spatial Perspective and Rotation Problems Through Language and Pictures

William Ives and Joel Rakow

Introduction

Piaget and Inhelder (1956) have argued that young children's difficulty in indicating another's viewpoint results from their inability to move beyond their own egocentric vantage point to utilize anticipatory imagery to envision the view of the other. However, as Flavell and others (Flavell, Omanson, & Latham, 1978; Salatas & Flavell, 1976) have noted, this task contains two separate developmental accomplishments: (1) the understanding of rules such as the concept that two observers will have a different view of an array if placed in different positions, and (2) the ability to perform computations, that is, the actual cognitive processes used to estimate the exact view of another.

The subsequent research on perspective taking concerned with the computations or cognitive processes involved in these tasks has frequently employed two types of tasks. In one task, similar to Piaget and Inhelder's (1956), the child is asked to select another's view of an array (hereafter called perspective task). In another task, the child is asked to imagine the array, itself, rotating to a new orientation and then select which view of the array would now be seen (hereafter called the rotation task).

While these tasks have been hypothesized to involve different cognitive processes, most accounts continue to suggest that some type of continuous, anticipatory imagery (i.e., the display is mentally rotated by the child) is used in both tasks (e.g., DeLisi & McGillicuddy-DeLisi, 1979; DeLisi, Locker, & Youniss, 1976; Harris & Bassett, 1976; Huttenlocher & Presson, 1973, in press). Recently, however, Olson and Bialystok (in press) and Palmer (1977) have put forth general theories of the development of spatial cognition which offer an alternative account for the above tasks. They argue that children organize space in terms of structural descriptions of the relevant features of objects and their relations rather than in terms of holistic images.

Thus, the child in the perspective task who uses the description of a feature such as the front or back of the object can simply note which feature is before the other viewer and not be required to mentally rotate the entire array. Since the child is focusing on distinct features of the object rather than the unit as a whole, the use of language rather than pictures as a response medium could facilitate correct responses in two ways. First, the use of language could aid children to focus on the features relevant to the task solution (e.g., front versus back) and thus foster the proper "selective organization" (Palmer, 1977) of the array. Second, since children are presumbly using discrete features rather

than a description of the array as a unit, language maps more directly on to the correct response. This process model would also predict that a decrease in the complexity of the features within the structural description (e.g., front vs. front corner) would facilitate correct scores. The use of objects with inherent structural descriptions (e.g., cars or houses rather than three cones representing mountains) should also improve scores.

Ives (in press) has provided evidence that in perspective problems, children's performances best fit the structural description model. The use of language as a response medium facilitated more correct responses than the use of pictures. The difficulty of the task was found to vary with the complexity of the structural description of the correct response whereas a variation in the rotational distance had no effect on scores. Moreover, the use of objects containing inherent structural descriptions (e.g., cars, houses) facilitated more correct responses than objects without such descriptions (i.e., three cones representing mountains).

The present study is designed to determine whether these previous findings occurred because language simply helps children solve all problems better than pictures, or because language was indeed linked to the particular cognitive processes used by children in the perspective task. Children were asked to perform one of two tasks: the perspective task of indicating another's view and the rotation task of imagining the view of an object once it is rotated. It is predicted that children will use the structural description process in the perspective task and the anticipatory imagery process in the rotation task.

Certain predictions for these variables follow from the use of these two distinct processes for each task. In the perspective task, the use of language will facilitate correct responses, the error pattern will vary with the complexity of the structural description of the correct response, and objects with inherent structural descriptions will facilitate correct responses. Conversely, in the rotation task, the use of language should facilitate scores, the error pattern should not vary with the complexity the structural description, and the nature of the stimulus object should not be an important variable.

Method

Subjects

The subjects were 96 children (equal numbers of boys and girls, kindergarten and second graders) attending an elementary school in a predominantly middle class suburb of Boston. Mean ages were five years, six months, and seven years, five months.

Apparatus and Materials

Two types of stimulus objects were placed on a small table in turn, those with inherent fronts, backs, and sides (a toy car, 5 cm. high by 18 cm.

long and a toy horse, 16 cm. high by 18 cm. long), and those without such inherent descriptions (two arrays of white cubes defined by black lines modelled after the drawings used in Shepard and Metzler's (1971) mental rotation study). The two object types will hereafter be called "canonical" for car and horse and "cubes". Four sets of five 10 cm. by 15 cm. black and white photographs of the above objects were used in the picture selection condition. The five photographs of each object represented the two description types: simple--the front, back, side, and complex--front corner and back corner. A black 35 mm. camera mounted on a tripod was used to mark the position of the other viewer in the perspective problem and served as the goal of rotation in the rotation problem. In the rotation condition each array object was placed on a round turntable 27 cm. in diameter with a green arrow attached (See Figure 1 for a diagram of the procedures).

Procedures

Perspective Task. Forty-eight (one half) of the 96 children were individually tested in one of the two response conditions: verbal or pictorial. In the verbal response condition each child was first shown a toy truck placed on a small table. A camera was placed beside the table, focused on the truck. The child was invited to look through the camera and describe the view. If the child failed to mention an orientation, the experimenter asked if the child saw the front (side, back) of the truck. To participate in the study, each child had to correctly use the terms "front", "front corner", "back", or "back corner", and "side"; all children reached this criterion. Next, the child was seated in front of the table and asked to play a game, pretending to take pictures. The child had to tell the experimenter what view of the object the camera would take from various positions, while the child remained seated.

The toy truck was used in a practice trial with corrective feedback; in the experimental task no feedback was provided. The camera was placed in positions of 180°, 135° and 45° from the child and the stimulus objects (single car, horse, and the two sets of cubes) were placed so the correct response varied equally between the two description types: simple structural descriptions (front, back, and side) and complex-structural descriptions (front corner and back corner) of the objects. In the case of the cubes, a horizontally protruding cube at the top of a column was designated as the front, and the other positions were designated accordingly. The presentation order of each object, the camera placement, the rotational distance, and the description of the correct response were counterbalanced and each child made a total of 16 responses in the experimental task.

In the picture-selection condition, the identical procedures were followed except that five photographs of the front, back, side, front corner, and back corner, of each object were used instead of the words indicating these positions. All children had to correctly match the pictures with the appropriate view of each object in order to participate in the study, and all children reached this criterion. In each condition, pictures and words, the child had five choices. The only difference between

conditions was that the five pictures were always presented for each trial, but the experimentor did not repeat the five verbal descriptions of each object once the problem was presented.

Rotation Task. In the rotation condition the array object was placed on a round turntable containing a green arrow pointing toward the child. The child was asked what view of the object he or she would see if the arrow were turned to particular positions 45°, 135°, 180° from the child. Aside from instructions, all aspects of the perspective and rotation tasks were equivalent. For conditions in which the camera was 180° opposite the child the correct answer was exactly the same in both tasks. In conditions where the camera was 135° and 45° from the child the correct answer was of equivalent structural complexity.

Results

Incidence of correct responses and egocentric responses was analyzed in two separate, non-independent 2 (grade) x 2 (task) x 2(response media) x 2 (sex) x 2 (description type) x 2 (object type) analyses of variance with repeated measures on description type and object type. Significant main effects for correct responses include: grade, $F(1,80) = 41.83$, $p < .001$, (K: 40.2%, 2: 60.5%), task, $F(1,80) = 11.59$, $p < .001$, (perspective = 55.8%, rotation = 44%), response media $F(1,80) = 68.13$, $p < .001$, (words: 62.8%, pictures: 42.7%), and description type, $F(1,80) = 38.98$, $p < .001$, (simple: 57.7%, complex: 42.7%) but not sex or object type. Significant main effects for egocentric responses include: grade, $F(1,80) = 9.05$, $p < .004$, (K: 25.4%, 2: 16.5%); task, $F(1,80) = 13.15$, $p < .001$, (perspective = 26.2%, rotation = 15.6%); response media, $F(1,80) = 46.39$, $p < .001$, (words = 10.8%, pictures = 30.9%); description type, $F(1,80) = 5.75$, $p < .02$, (simple = 19.2%, complex = 22.2%). See Table 1 for the correct and egocentric responses grouped by the variables with significant main effects.

A significant task x response media interaction for both correct responses, $F(1,80) = 47.51$, $p < .001$, and egocentric responses, $F(1,80) = 52.61$, $p < .001$, indicates that words greatly facilitate correct responses in the perspective task but not in the rotation task (See Table 2). Egocentric responses are most likely to occur in the picture selection condition of the perspective task. In contrast, in the rotation task the response medium appears to have little effect on egocentric responses.

A significant task x response media x description type interaction, $F(1,80) = 4.18$, $p < .05$ (See Table 3), indicates that, in the picture condition in the rotation task, there is little difference between the use of simple and complex structural descriptions for correct responses. In contrast, in the picture condition of the perspective task, the use of simple structural descriptions greatly facilitates correct responses.

The significant task x response media x object type interaction, $F(1,80) = 11.44$, $p < .001$ (See Table 4), indicates that in the verbal condition, objects with inherent structural descriptions do provide a greater facilitation in the perspective task than in the rotation task. Also, the significant task x description type x object type interaction, $F(1,80) = 4.37$, $p < .04$

(See Table 5), indicates that, when the correct answers require simple structural descriptions, objects with inherent structural descriptions provide a greater facilitation in the perspective task than in the rotation task.

Discussion

The results support the position that different cognitive processes are involved in perspective and rotation tasks. In the perspective task the use of language greatly facilitates correct responses but this factor contributes only marginally in the rotation task. Egocentric responses are primarily confined to the picture condition of the perspective task. In addition, the occurrence of correct responses requiring simple structural descriptions greatly facilitates scores in both the verbal and picture condition of the perspective task. In contrast, in the rotation condition, the simplicity of the structural description of the correct responses has little effect within the picture condition (where structural descriptions are not explicitly supplied). Also, the use of objects with inherent structural descriptions provides a greater facilitation in the perspective task than in the rotation task within the verbal condition. The reverse is true in the picture condition, where children are not explicitly supplied with the structural descriptions. Moreover, when simple structural descriptions can be used for the correct answer, the use of objects with inherent structural descriptions provides a greater facilitation in the perspective task than in the rotation task.

The results support the position that spatial perspective taking involves a computation process using structural descriptions of features of objects rather than a process of mental rotation of the object as a whole unit using anticipatory imagery. This latter process is more likely to occur in rotation tasks explicitly calling for such an operation.

The results and those of previous studies (Ives, in press a,b) suggest that children's errors in perspective tasks using picture selection as a response mode are primarily due to a failure to utilize the rule that persons in a different vantage point see a different view. The discrete alternatives provided by language offer the proper "selective organization" (Palmer, 1977), eliminate extraneous information, and thus facilitate utilization of the correct rule. The difficulty of the computation process in the perspective varies with the structural difficulty of the correct response; when the correct response only requires a simple structural description young children have little difficulty with the computation process. Previous research (Ives, in press b) indicates that even three year olds could do this task 90 percent of the time in such conditions. In contrast, the rotation task errors appear to result primarily from difficulties in the computation process. As relatively few egocentric errors occur in either response medium, children appear to have mastered the rule that, when an object is rotated away from them, they will see a different view. However, they have greater difficulty with the computation process of the rotation task than with that of the perspective task.

The results also underline the importance of finding the appropriate response medium for the task (e.g., Olson, 1976; Salomon, 1979). When allowed to respond verbally, children have little difficulty with perspective problems; moreover, contrary to previous studies which did not have a verbal response condition (e.g., Huttenlocher & Presson, 1973), children find perspective problems easier than rotation problems. When using picture selection, however, rotation tasks are easier, a result consistent with previous findings.

While previous research has also shown that the nature of the object within the array is an important variable, (e.g., Borke, 1975; Fishbein, Lewis, & Keiffer, 1972; Shlechter, 1977) the present findings put this variable into a theoretical context. An examination of the previous studies mentioned above indicates that the use of objects with inherent structural descriptions facilitates correct responses. This claim is supported in the present study but only within the perspective task.

The findings of this study indicate that the mental computations used in problem solving are not wholly determined by the surface characteristics of the task (i.e., whether it is couched in a visual-spatial or verbal form); also relevant is the extent to which either more explicit structural descriptions of features or more complex holistic images are both called for and utilized. If these assumptions are correct, then one task of further research is to move beyond the traditional spatial-verbal dichotomy, determine the actual processes used to solve the problems children encounter and develop training strategies utilizing the appropriate medium. Not all spatial problems are best presented through pictures, nor is language always a facilitator of correct solutions to problems.

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Table 1

Mean Percent of Correct & Egocentric Responses

Grade Level		Perspective				Rotation			
		Verbal		Pictorial		Verbal		Pictorial	
		S*	C	S	C	S	C	S	C
Kindergarten:	Correct	92.7**	56.1	19.8	9.4	56.3	18.8	39.6	32.3
	Egocentric	2.0	12.4	56.3	59.4	9.4	16.7	20.7	25.0
Second Grade:	Correct	86.4	86.5	59.4	35.4	64.6	50.0	52.1	49.0
	Egocentric	2.0	5.2	31.3	40.6	23.0	15.6	8.4	5.3

*S = correct response requires a simple structural description

C = correct response requires a complex structural description

**Chance level in all tables is 20 percent.

Table 2

Mean Percent of Responses by Response Type

Response Media	Perspective Task			Rotation Task		
	Correct Response	Egocentric Response	Other Response	Correct Response	Egocentric Response	Other Response
Words	79.0	5.4	15.6	46.7	16.2	37.1
Pictures	32.6	47.0	20.4	42.5	14.9	42.6

Tasks x Media Interaction: Correct Responses $F(1,80) = 47.51$, $p < .001$

Egocentric Responses $F(1,80) = 52.61$, $p < .001$

Table 3

Mean Percent of Correct Responses

Complexity of Correct Response	Perspective Task		Rotation Task	
	Words	Pictures	Words	Pictures
Simple	89.5	39.6	60.5	44.3
Complex	71.4	25.5	32.9	40.7

Table 4

Mean Percent of Correct Response

Task	Verbal Condition		Picture Condition	
	Canonical	Cube	Canonical	Cube
Perspective	82.3	75.5	30.7	34.4
Rotation	45.3	47.9	50.5	34.3

Table 5

Mean Percent of Correct Response

Complexity of Correct Response	Perspective Tasks		Rotation Tasks	
	Canonical	Cube	Canonical	Cube
Simple	67.1	58.4	54.7	50.0
Complex	45.3	51.6	41.1	32.3

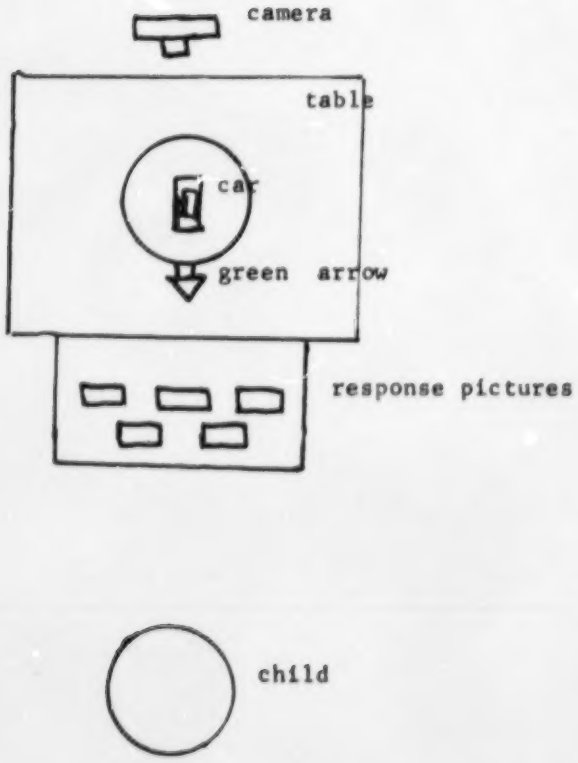

Figure 1. Experimental Procedures: Picture Selection Condition, Rotation Task.

Harvard Project Zero is a basic research program at the Harvard Graduate School of Education. Its original charge was to study creation and comprehension in the arts and means toward better art education. A prime objective throughout the Project's history has been to provide a sound theoretical and experimental base for effective education of artists and audiences. The Project began in the fall of 1967 in response to the frank admission that, however much is known about how to educate in science and how to evaluate scientific work, practically nothing is known about the underlying principles of how to teach and evaluate in art. From that challenging "zero" the Project took its name and tasks. Our research methods include rigorous conceptual analysis, investigation of relevant literature, design and execution of key experiments in psychology and other fields, visits to arts education institutions, and application of results to proposing and assessing programs in art education.

Project founder and former director Nelson Goodman's book Languages of Art (Bobbs-Merrill, 1968) has provided important direction in our effort to isolate and investigate basic skills. This work sets forth a "theory of symbols," a broad treatment of elements of communication, embracing words, gestures, diagrams, paintings, poems, musical scores, and so on. Almost all the psychological processes under consideration in our studies of the arts involve extensive operation with and upon symbols of various kinds. These symbols are not merely instruments of communication, but also instruments of cognition, tools in terms of which the mind deals with the perceptual world.

Some of our research has examined the psychological implications of the theoretical models of symbol systems introduced in Languages of Art. For instance, one question is whether different information processing skills are necessary to produce effective art within linguistic, versus nonlinguistic, symbol systems. Another, complementary approach emphasizes problem solving and search strategies in the moment-to-moment perception and production of a work of art. How do subjects search for rhyme words in poetry or explore alternative placements of pieces in collage? A favorite means of developing and testing new models is through the study of errors. By using impoverished or ambiguous stimuli, assigning tasks somewhat too difficult for a subject, or working with brain-damaged subjects, one can elicit patterns of error-making which suggest hypotheses and select between alternative models of a process. These approaches characterize many of the Project's investigations mentioned below in a list of Project members and their particular interests.

Though the development of actual curricula in arts education is not a primary concern, the Project does contribute to the field of practical education. Project members have responded to inquiries and requests to comment on curricula from teachers in the field. Establishment of Harvard Summer School's Institute in Arts Administration resulted from the Project's reply to an inquiry from the director of the Harvard Summer School, and members of the Project staff cooperated in planning the Institute, in preparing material, and in the actual teaching. Consideration consultation has been provided to schools, museums, television, and a variety of arts institutions by members of the Project.

The Project has also sponsored a series of lecture-performances in various media, designed to give the general public and prospective public school teachers and administrators better insight into and attitudes towards artists and the arts. As the series title "Art in the Making" suggests, the purpose of the lecture-demonstrations was to reveal something of the artist's way of working, rather than to display his products. In the presence of an audience free to ask questions, each artist explored alternatives, exposed some constraints of his medium, compared his various efforts, and searched for the right effect, choice by choice.

While maintaining a major concern with the arts and art education, the Project, under its current co-directors, has considerably broadened its field of inquiry and now investigates a whole range of topics in the area of cognitive psychology. One part of the Project has focussed particularly on developmental studies. Among the topics currently being investigated are the emergence of symbolic capacities during the first years of life; the development of literary abilities, specifically the capacity to produce and appreciate metaphors and stories; children's understandings of the various worlds presented on television; the emergence of drawing skills; and the breakdown of various symbol using capacities under various forms of brain damage. The other part of the Project has concentrated on studies in the areas of cognitive and perceptual psychology, ones which utilize both normal adult subjects and gifted artists. Among the topics investigated recently have been critical judgment and the sources of critical disagreement in adults; the thought processes of professional and amateur poets and painters in developing works; the role of geometric principles in visual perception and picture perception particularly; reasoning about everyday matters and the logical difficulties people encounter.

A list of recent papers which can be purchased from the Project is available upon request.